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14. ABSTRACT The monitoring mission requires accurate yield estimation for nuclear explosions. Historically, the focus has been on larger yield events ($mb > -4.5$) using teleseismic body wave magnitudes and applying test-site-specific corrections for yield estimates. The regional coda methodology provides unprecedented stability and avoids test site bias because it is based upon absolute source spectra. Increasingly however, there is interest in monitoring smaller events both for yield and source characterization. Unfortunately, these events may only be recorded with adequate signal-to-noise ratio at local distances from one station. The project goals were to extend the well-established regional coda methodology to local distances using <i>S</i> and <i>P</i> -wave codas in regions of little to no calibration data and/or regions of high attenuation and lateral complexity. Previous studies show that local coda has a unique property of homogenizing its energy over a volume of the Earth's crust such that path corrections for distances less than ~200 km are not necessary or minimal at worst. The recent 2008 <i>Mw</i> 5.8 Wells, Nevada earthquake was well recorded by the U.S. Array and we show that the local-to-near-regional coda is virtually insensitive to the source radiation pattern and directivity effects. Furthermore, we demonstrate the coda wavefield becomes homogenized a few tens of seconds past the expanding direct-wave front. This past year, we have also calibrated a number of paths in Japan and compare those to our previous years' work. We have compared <i>S</i> -wave coda path attenuation curves, envelopes shapes, and peak velocity from a variety of regions to look for similarities and differences that could be correlated to the degree of tectonic activity. This special feature may make it easier to define an <i>a priori</i> set of coda calibration parameters that can be transported to new, but geophysically similar regions. For example, it appears that tectonically similar regions have similar coda path, envelope shape, and peak envelope velocity which will allow us to derive average 'local background' models then apply them to other regions for testing and evaluation, including cases to mimic an uncalibrated, single-station deployment.					
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SMALL EVENT YIELD AND SOURCE CHARACTERIZATION USING LOCAL *P* AND *S*-WAVE CODA
SOURCE SPECTRA

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Sponsored by the Air Force Research Laboratory

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ABSTRACT

The monitoring mission requires accurate yield estimation for nuclear explosions. Historically, the focus has been on larger yield events ($m_b > \sim 4.5$) using teleseismic body wave magnitudes and applying test-site-specific corrections for yield estimates. The regional coda methodology provides unprecedented stability and avoids test site bias because it is based upon absolute source spectra. Increasingly however, there is interest in monitoring smaller events both for yield and source characterization. Unfortunately, these events may only be recorded with adequate signal-to-noise ratio at local distances from one station. The project goals were to extend the well-established regional coda methodology to local distances using *S* and *P*-wave codas in regions of little to no calibration data and/or regions of high attenuation and lateral complexity. Previous studies show that local coda has a unique property of homogenizing its energy over a volume of the Earth's crust such that path corrections for distances less than ~ 200 km are not necessary or minimal at worst. The recent 2008 M_w 5.8 Wells, Nevada earthquake was well recorded by the U.S. Array and we show that the local-to-near-regional coda is virtually insensitive to the source radiation pattern and directivity effects. Furthermore, we demonstrate the coda wavefield becomes homogenized a few tens of seconds past the expanding direct-wave front. This past year, we have also calibrated a number of paths in Japan and compare those to our previous years' work. We have compared *S*-wave coda path attenuation curves, envelope shapes, and peak velocity from a variety of regions to look for similarities and differences that could be correlated to the degree of tectonic activity.

This special feature may make it easier to define an *a priori* set of coda calibration parameters that can be transported to new, but geophysically similar regions. For example, it appears that tectonically similar regions have similar coda path, envelope shape, and peak envelope velocity which will allow us to derive average 'local background' models then apply them to other regions for testing and evaluation, including cases to mimic an uncalibrated, single-station deployment.

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RESEARCH ACCOMPLISHED

For this year, we have studied the near-regional Lg-coda from the M_w 6.0 Wells, Nevada earthquake of February 21, 2008, as well as a local M_w 4.2 event from the San Francisco Bay area that exhibited a clear case of source directivity. The Wells event sequence was unique because the U.S. Array broadband seismic deployment had recorded this event along with its aftershocks, thus providing excellent station coverage and redundancy. Figure 1 below shows that the local to near-regional coda is very stable in comparison to the direct Lg. We have formed amplitude ratios, in this case 3.5 Hz, between the mainshock and a selected aftershock. The coda velocity and envelope shape functions were found to be virtually identical from station to station, in spite of significant geologic variation for paths traveling east versus those to the north and north-west. Though this event did not exhibit strong directivity, we still see a radiation pattern in the direct Lg ratios, or perhaps random variation between the two sources. However for the coda, we see significantly less variation, confirming that the coda is not sensitive to the source mechanism.

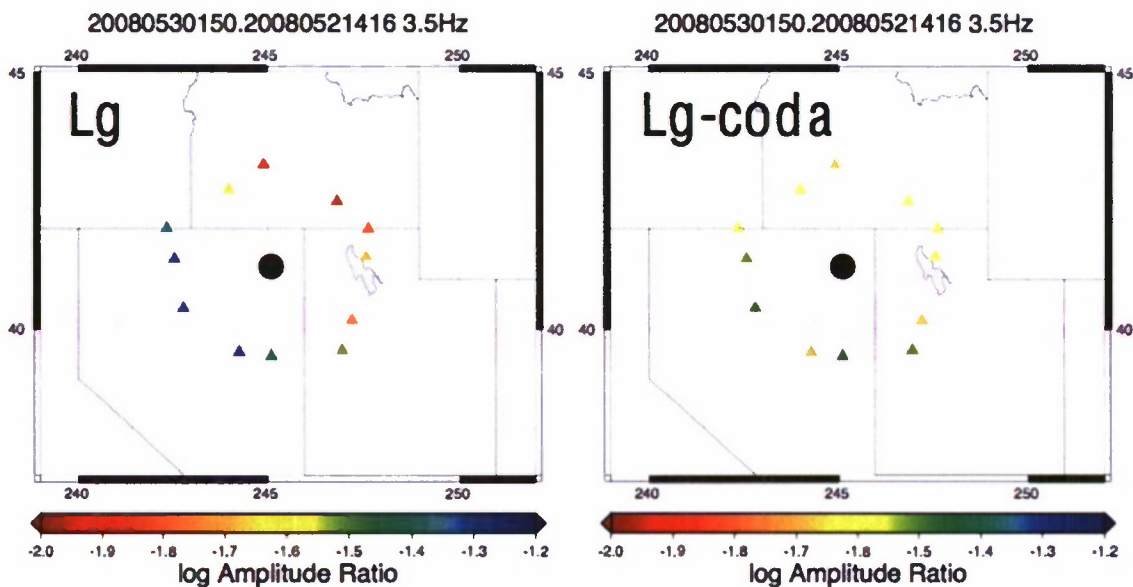


Figure 1. Left figure above shows source ratios for Lg at 3.5 Hz for 12 stations surrounding the Wells mainshock region, roughly 200 km in epicentral distance. We observe large variations even though path and site response are removed by forming the source amplitude ratio. In sharp contrast, the right figure shows the coda-derived source ratios for the same event pair and frequency. As found in other studies, the coda is significantly less variable.

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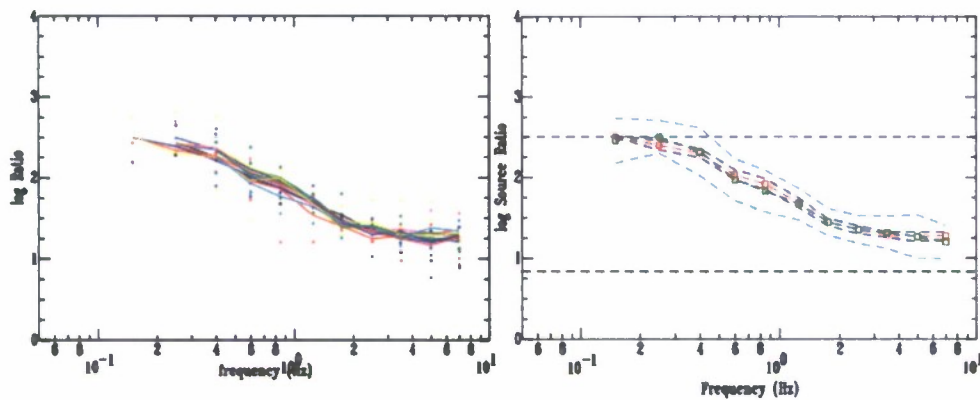


Figure 2. Left figure above shows spectral ratios taken between the Wells mainshock and a co-located aftershock. Solid lines represent coda ratios at the 12 stations and colored dots are the direct Lg source ratios. All stations are roughly 200 km in distance. The figure on the right shows the average and standard deviation for both coda and Lg. For the coda, red is the mean and blue is the ± 1 standard deviation and for Lg, green is the mean and light blue is the ± 1 standard deviation.

For our second example, we studied an M_w 4.2 event that occurred along the Hayward fault in the San Francisco Bay area. This event was very interesting because there were seismic stations equi-distance from the mainshock along the strike of the Hayward fault. The mainshock exhibited over a factor of 10 larger amplitude in the north-westerly direction (along strike) relative to the south-east direction. The figure below shows that station CVS to the northwest has much larger direct wave amplitudes than station MHC to the southeast, however the coda envelopes are exactly the same after a few tens of seconds. In addition, an aftershock for the same stations and frequency bands does not show any directivity.

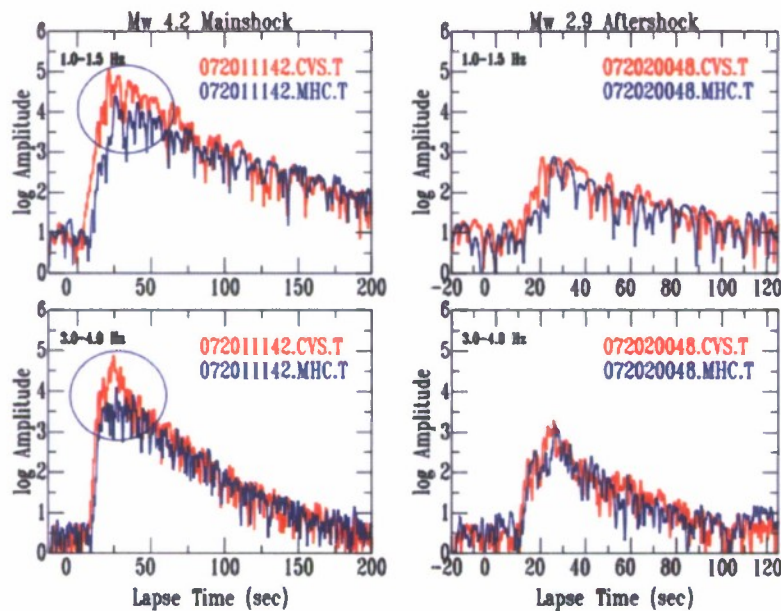


Figure 3. We show a clear case of source directivity (left column) that results in roughly a factor of 10 larger amplitude for the direct waves at station CVS, located to the north of the event and along strike relative to station MHC located to the south. However, the coda levels at both stations are identical. An aftershock shows no evidence of directivity (right column).

We have continued calibrating local and near-regional coda envelopes for a variety of different regions (Figure 4). We have used the same procedure outlined in prior applications of the coda methodology from Mayeda et al. (2003).

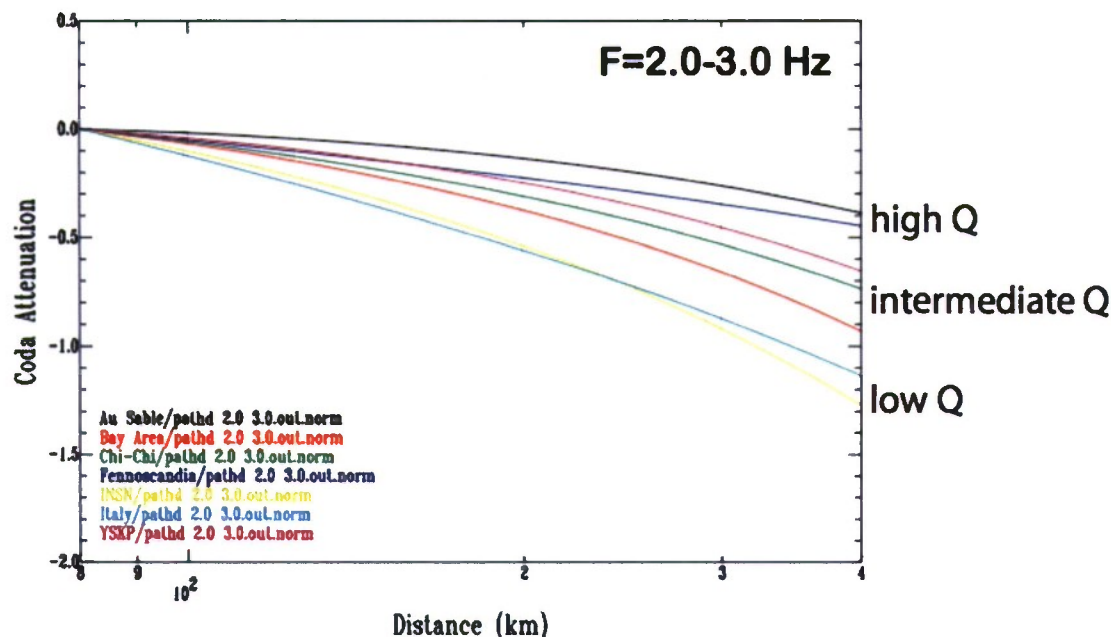


Figure 4. Coda path attenuation for the 2.0-3.0Hz band for seven different regions. In general, we find that tectonically stable regions (e.g., Korea and New York) exhibit the highest Q whereas active regions have much steeper decay (e.g., Iran and Italy).

In general, we can make some preliminary statements on similarities and differences between all the regions studied so far. First, we find that central Italy exhibits the strongest attenuation, followed by Taiwan and western Iran for distances ranging between ~20 and 300 km. On the other hand, Upstate New York and the Korean Peninsula appear to have the lowest attenuation, which is reassuring since both regions are the most tectonically stable. The San Francisco Bay Area is somewhere between the two. We are now looking into datasets in Japan and those results will be forthcoming.

CONCLUSIONS AND RECOMMENDATIONS

In addition to our research of gathering coda envelope shape, path attenuation, and peak envelope velocity information from a variety of tectonic regions (see previous reports), we have also begun to document the coda's property of insensitivity to both the source radiation pattern and directivity. The examples shown in Figures 1, 2, and 3 are strong evidence that the coda's averaging properties also applies to the source heterogeneity, not just path heterogeneity. We still need to look at coda shape parameters that should also be very region dependent, as evidenced by many local coda Q studies in the literature. At this point, we are on track with our proposed statement of work and are forging ahead. This still leaves our local P-coda calibration study that will happen in the mid-part of 2009. In our preliminary research, we have also compared coda attenuation parameters for seven different regions for frequencies ranging between 0.5 and 8.0 Hz and are working on a number of sequences in Japan. We will continue to document other regions from which to compare and draw final conclusions. We still need to look at coda shape parameters that should also be very region dependent, as evidenced by many local coda Q studies in the literature. At this point, we are on track with our proposed statement of work and are forging ahead.

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Mayeda, K., A. Hofstetter, J. L. O'Boyle, and W. R. Walter (2003). Stable and transportable regional magnitudes based on coda-derived moment-rate spectra, *Bull. Seismol. Soc. Am.* 93: 224-239.